

Investigation of potentially contaminated sites — Code of practice

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- Association of Metropolitan Authorities
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Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
Introduction	1
1 Scope	1
2 Normative references	2
3 Terms and definitions	2
4 Setting the objectives of an investigation	4
4.1 General	4
4.2 Guidance on drawing up detailed objectives	4
4.3 Examples of typical investigations and applications	6
5 Establishing an investigation strategy	6
5.1 General	6
5.2 Outline of strategy	6
5.3 Preliminary investigation	8
5.4 Exploratory investigation	8
5.5 Main investigation	9
5.6 Supplementary investigation	9
5.7 Investigation strategy	10
6 Preliminary investigation	11
6.1 General	11
6.2 Data collection	12
6.3 Interpretation and reporting	15
7 Design and planning of field investigations	16
7.1 General	16
7.2 Integrated investigations	17
7.3 Personnel and environmental protection	17
7.4 Pre-investigation considerations	17
7.5 Method of field investigation	18
7.6 Sampling strategies	19
7.7 Design of testing requirements	28
7.8 Quality assurance (QA) and quality control (QC)	29
8 Fieldwork	29
8.1 General	29
8.2 Techniques	29
8.3 Sampling	38
8.4 On-site testing	44
8.5 Sample containers	45
8.6 Sample labelling, preservation and handling	46
8.7 Sampling report	46
9 Off-site analysis of samples	47
9.1 General	47
9.2 Choice of laboratory	47
9.3 The assessment and control of errors in sub-sampling and analysis	48
9.4 Selection of contaminants for analysis	48
9.5 Preparation of samples for analysis	49
9.6 Analysis of samples	49

9.7	Geotechnical and other testing of soils	51
10	Reports	51
10.1	General	51
10.2	Preliminary investigation report	51
10.3	Intrusive investigation report	52
Annex A (informative)	Examples of site investigations	55
Annex B (informative)	Health and safety in site investigations	65
Annex C (informative)	Typical gas monitoring well construction	67
Annex D (informative)	Collection of a representative sample by means of a “nine point sample”	68
Annex E (informative)	Suitability of sample containers	69
	Bibliography	71
Figure 1	— Schematic approach to site investigation	7
Figure 2	— Considerations in the selection of intrusive investigation method	38
Figure A.1	— Site plan: Example 1	56
Figure A.2	— Site plan: Example 2	61
Figure C.1	— Typical gas monitoring well construction	67
Figure D.1	— Nine point sampling pattern	68
Table 1	— Typical objectives of the different phases of an investigation	5
Table 2	— Preliminary investigation	11
Table 3	— Types of available information	12
Table 4	— Phasing groundwater investigations	23
Table 5	— Methods of non-intrusive investigation	30
Table 6	— Methods of intrusive investigation	34
Table 7	— Selection of suitable investigation method for different ground types	39
Table 8	— Physical requirements of different investigation methods	39
Table 9	— Types of sample	41
Table B.1	— Health and safety measures for site investigations	66
Table E.1	— Suitability of sample containers	69

Foreword

This British Standard has been prepared by EH/4/2, Sampling. It supersedes DD 175:1988 which is withdrawn.

It is now consistent with current methodologies and has been updated considerably since the publication of DD 175.

Attention is drawn to the following primary legislation and the statutory regulations made under these various acts and under European Directives enacted that are relevant to safety, environmental protection and construction works:

- The Factories Act, 1961 [1];
- Offices, Shops and Railway Premises Act, 1963 [2];
- The Health and Safety at Work, etc. Act, 1974 [3];
- The Control of Pollution Act 1974 and The Control of Pollution (Amendment) Act, 1989 [4];
- The Water Act 1989 [5];
- The Environmental Protection Act, 1990 [6];
- The Water Resources Act, 1991 [7];
- The Environment Act, 1995 [8];
- The Town and Country Planning Act [41];
- The Building Control Act [42];
- The Construction Design and Management Regulations (CDM regulations), 1995 [9];
- Control of Substances Hazardous to Health Regulations, 1988 [10];

DETR/Environment Agency are currently developing a Handbook of Model Procedures for the Management of Contaminated Land. It is intended to review this code of practice when the Handbook has been published.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 75 and a back cover.

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Introduction

The guidance in this British Standard is applicable to the investigation of all potentially contaminated sites and also to land with naturally enhanced concentrations of potentially harmful substances.

The management of contaminated land involves identifying risks due to the presence of *contaminants*, in order that appropriate action can be taken. The risk assessment of a potentially contaminated site requires information to characterize the contamination status. This information is gathered by a process of site investigation as set out in this standard. The information required comprises:

- details of the historical setting of the site and the potential for the presence of *contaminants*;
- identification of who or what could be affected by the *contaminants* (i.e. *receptors*);
- information on the *pathways* by which *contaminants* could migrate or come into contact with *receptors* (including details of any physical characteristics of the site that will affect *contaminant* movement).

The results of the investigation should define all known aspects of the site that could impinge upon or affect the *contaminant — pathway — receptor* scenario and is referred to as the *conceptual model*.

The *conceptual model*, resulting from the preliminary investigation (desk study), is used to focus subsequent investigations, where these are necessary, to meet the objectives of the overall investigation. However, the use of the *conceptual model* to assess the requirement for remedial action is a part of the risk assessment process. Guidance on how to carry out a risk assessment is outside the scope of this standard. For guidance on risk assessment see CIRIA publication SP103 [11] and CIWEM publication [47].

NOTE 1 Guidance on the management of contaminated land is in the process of preparation and will be published by the Department of the Environment, Transport and Regions (DETR) and the Environment Agency [12]. When published that document will also provide guidance on the assessment of contaminated land. It can be used in conjunction with the recommendations given in this standard. Particular attention is drawn to Part III, Procedure for risk assessment.

NOTE 2 The process of investigation is likely to involve a number of stages each with different detailed objectives and utilizing a range of technologies. At the end of each stage the information obtained should be reviewed to determine if the objectives have been met and if there is a need for further investigation. Where further investigation is necessary the design of the next stage should be based on and utilize the information previously obtained.

NOTE 3 Some requirements for investigation may lie beyond the needs of a risk assessment, for example a validation-sampling scheme or the selection and detailed design of a remediation scheme. In such situations it should be possible to use the procedures given in this British Standard to design the relevant investigation.

1 Scope

This British Standard provides guidance on, and recommendations for, the investigation of potentially contaminated land or land with naturally enhanced concentrations of potentially harmful materials, to determine or manage the ensuing risks. It covers:

- setting the objectives of an investigation;
- setting a strategy for the investigation;
- designing the different phases of the investigation;
- sampling and on-site testing;
- laboratory analysis;
- reporting;

in order to obtain scientifically robust data on soil, groundwater, surface water and ground gas contamination.

It is intended for use by those with some understanding of the risk-based approach to sites and site investigations.

The relevant guidance and recommendations within this standard should be selected to ensure that the objectives of an investigation are achieved and that adequate data for the risk assessment are obtained. However, it is not feasible to provide detailed guidance for every possible investigation scenario.

This British Standard does not give recommendations on certain constraints or problems that can affect a site, such as geotechnical aspects, [which are covered by BS 5930 (see 7.2)], or the legal aspects, including the need for licences, permits, etc.

It does not include any procedures for the formal assessment of the potential risks posed by contaminated land. However, attention is drawn to the guidance published by CIRIA in SP103 [11] and CIWEM [47].

NOTE The Handbook of Model Procedures [12] which is in the process of development by the DETR and the Environment Agency, will also be a source of guidance on risk assessment when published.

When relevant, this standard can be used in conjunction with other standards and codes of practice for combined investigations, such as in conjunction with geotechnical investigations.

2 Normative references

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 1017 (all parts), *Sampling of coal and coke*.

BS 1377 (all parts), *Methods of test for soils for civil engineering purposes*.

BS 1747 (all parts), *Methods for measurement of air pollution*.

BS 5930:1999, *Code of practice for site investigations*.

BS 6068-6.4, *Water quality. Sampling. Guidance on sampling from lakes, natural and man-made*.

BS 6068-6.5, *Water quality. Sampling. Guidance on sampling of drinking water and water used for food and beverage processing*.

BS 6068-6.6, *Water quality. Sampling. Guidance on sampling of rivers and streams*.

BS 6068-6.11, *Water quality. Sampling. Guidance on sampling of groundwaters*.

BS 6068-6.12, *Water quality. Sampling. Guidance on sampling of bottom sediments*.

BS 6068-6.14, *Water quality. Sampling. Guidance on quality assurance of environmental water sampling and handling*.

BS 6069, (all parts), *Characterization of air quality*.

BS 6187, *Code of practice for demolition*.

BS 7755 (all parts), *Soil quality Chemical methods*.

BS 8855 (all parts), *Soil analysis*.

BS EN 25667-1, *Water quality: Sampling — Part 1: Guidance on the design of sampling programmes* (dual numbered as BS 6068-6.1).

BS EN 25667-2, *Water quality: Sampling — Part 2: Guidance on sampling techniques* (dual numbered as BS 6068-6.2).

BS EN ISO 5667-3, *Water quality: Sampling — Part 3: Guidance on the preservation and handling of samples* (dual numbered as BS 6068-6.3).

3 Terms and definitions

For the purposes of this British Standard the following terms and definitions apply.

3.1

accuracy

level of agreement between true value and observed value

3.2

conceptual model

textual and/or schematic hypothesis of the nature and sources of contamination, potential migration pathways (including description of the ground and groundwater) and potential receptors, developed on the basis of the information from the preliminary investigation and refined during subsequent phases of investigation and which is an essential part of the risk assessment process

NOTE The conceptual model is initially derived from the information obtained by the preliminary investigation. This conceptual model is used to focus subsequent investigations, where these are considered to be necessary, in order to meet the objectives of the investigations and the risk assessment. The results of the field investigation can provide additional data that can be used to further refine the conceptual model.

3.3

contamination

presence of a substance which is in, on or under land, and which has the potential to cause harm or to cause pollution of controlled water

NOTE 1 There is no assumption in this definition that harm results from the presence of the contamination.

NOTE 2 Naturally enhanced concentrations of harmful substances can fall within this definition of contamination.

3.4**controlled water**

inland freshwater (any lake, pond or watercourse above the freshwater limit), water contained in underground strata and any coastal water between the limit of highest tide or the freshwater line to the three mile limit of territorial waters

NOTE See Section 104 of The Water Resources Act 1991 [7].

3.5**harm**

adverse effect on the health of living organisms, or other interference with ecological systems of which they form part, and, in the case of humans, including property

3.6**hazard**

inherently dangerous quality of a substance, procedure or event

3.7**pathway**

mechanism or route by which a contaminant comes into contact with, or otherwise affects, a receptor

3.8**precision**

level of agreement within a series of measurements of a parameter

3.9**receptor**

persons, living organisms, ecological systems, controlled waters, atmosphere, structures and utilities that could be adversely affected by the contaminant(s)

3.10**risk**

probability of the occurrence of, and magnitude of the consequences of, an unwanted adverse effect on a receptor

3.11**risk assessment**

process of establishing, to the extent possible, the existence, nature and significance of risk

3.12**sampling**

methods and techniques used to obtain a representative sample of the material under investigation

3.13**soil**

upper layer of the earth's crust composed of mineral parts, organic substance, water, air and living matter [BS 7755-1.4:2000]

NOTE For the purposes of this British Standard the term soil has the meaning ascribed to it through general use in civil engineering and includes topsoil and subsoils; deposits such as clays, silt, sand, gravel, cobbles, boulders and organic deposits such as peat; and material of natural or human origin (e.g. fills and deposited wastes). The term embraces all components of soil, including mineral matter, organic matter, soil gas and moisture, and living organisms.

3.14**source**

location from which contamination is, or was, derived

NOTE This could be the location of the highest soil or groundwater concentration of the contaminant(s).

3.15**target**

see **receptor**

3.16**uncertainty**

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurement

4 Setting the objectives of an investigation

4.1 General

The objective of a site investigation will be to gather the information needed to form a *conceptual model* in order to be in a position to assess the presence and significance of contamination of land (or in the case of naturally occurring material, the significance of the concentrations present). The resultant information then enables the risk assessment to be carried out to conclusions in which an acceptable degree of confidence can be placed.

At any of the various stages of an investigation, the overall objectives will be to characterize the *contaminants* present and to identify *pathways* and *receptors* for the purposes of the risk assessment. The information required in order to carry out the risk assessment to a robust conclusion should be identified before designing or planning an investigation.

The investigation of land for the presence of contamination or naturally occurring enhanced concentrations of harmful substances is driven by the need to assess the risks associated with a site. The objectives of a risk assessment, and a site investigation, are determined by the purpose for which the risk assessment is required. The risk assessment that is identified as fulfilling the requirements of the purchaser of that process (the client) determines the objectives of a site investigation.

The objectives of a site investigation will vary, depending upon the stage in the process that has been reached, and the underlying intentions for the land involved. Objectives may for example be to:

- define or clarify a *conceptual model*;
- support a risk assessment;
- provide data for the design of remedial works;
- benchmark the contamination status of a site.

4.2 Guidance on drawing up detailed objectives

The following guidance applies when drawing up the objectives.

- a) The questions that information from the investigation will be used to resolve should be identified.
- b) The information that is needed, the measurements required, the level of detail and the accuracy that is required to resolve the questions should be determined.
- c) The investigation boundaries, both spatially and temporally, should be defined.
- d) In the context of providing information for a risk assessment, the purpose of the risk assessment should be defined.

As information is developed during an investigation, it is essential to consider the impact on the objectives and to review the objectives to determine if these require modification or extension.

The formulation and refinement of a *conceptual model* is always one of the objectives and, as more information is obtained, the model should be reviewed and revised in the context of the additional information.

Table 1 sets out typical detailed objectives that can be associated with different stages of an investigation.

The selection and design of remedial measures may require additional information, for example geotechnical data.

Although the general objectives will always be similar for the risk assessment process, the detailed objectives and the amount of information which will be adequate to give the subsequent assessment sufficient confidence will vary according to the reason for carrying out the assessment and the investigation.

Further information on setting objectives can be obtained from EPA QA/G-4 [11].

NOTE In some circumstances benefits can be gained from investigations that combine the needs of contamination and geotechnical objectives. However, the use of an integrated investigation should not be allowed to compromise the objectives or requirements of either investigation (see 7.2).

Table 1 — Typical objectives of the different phases of an investigation

Phase	Typical objectives
Preliminary investigation (clause 6)	To provide information on past and current uses of the site and surrounding area, and the nature of any hazards and physical constraints.
	To identify <i>receptors</i> , potential sources of contamination and likely pathways and any features of immediate concern.
	To provide information on the geology, geochemistry, hydrogeology and hydrology of the site.
	To produce an initial <i>conceptual model</i> of the nature and extent of potential contamination (see 6.3.1).
	To provide data for preliminary risk assessment (see 6.3.2).
	To enable informed decisions to be made on the need for specialist assessment e.g. if there are ecological or archaeological considerations.
	To provide data to assist the design of <i>exploratory</i> and <i>main investigations</i> and to give an early indication of possible remedial requirements.
	To provide information relevant to worker health and safety, and to the protection of the environment during field investigations (annex B).
	To identify the need to involve regulatory bodies prior to intrusive investigation.
Exploratory investigation (optional)	To test the <i>conceptual model</i> of contamination and site characteristics.
	To obtain further information in relation to potential sources of contamination, likely pathways, features of immediate concern.
	To obtain further information on the geology, geochemistry, hydrogeology and hydrology of the site.
	To provide further information to aid the design of the <i>main investigation</i> , including health and safety aspects.
	To provide data for a review of the <i>conceptual model</i> and to update the risk assessment.
Main investigation	To obtain data on the nature and extent of contamination, the geology, geochemistry, hydrogeology and hydrology of a site.
	To provide data to review the <i>conceptual model</i> and to update the risk assessment.
	To provide data for the selection and design of remedial methods.
Supplementary investigation(s) (optional)	To provide clearer delineation of a particular area of contamination or a contamination plume.
	To address or clarify specific technical matters (e.g. to confirm the applicability and feasibility of potential remedial options).
NOTE For the purposes of this British Standard, information on geology includes made ground and fill.	

4.3 Examples of typical investigations and applications

The following examples are typical of the types of investigations that are carried out and the types of applications for which they are used.

a) *Objectives of investigation*: to provide information for the development of an initial *conceptual model* of the site and the potential *contaminant-pathway-receptor* scenarios, and the assessment of potential risk (desk study, see Table 1 and preliminary investigation, clause 6).

NOTE Different *conceptual models* may be formulated for different areas and development stages of a site (see 5.3).

Typical application: the first stage in any contaminated land assessment. There may be a need for further investigation to confirm the *conceptual model* postulated, or the information obtained may be considered adequate for the decisions to be made, e.g. pre-purchase assessment.

b) *Objectives of investigation*: to confirm a *conceptual model* and confirm whether proposed *contaminant-pathway-receptor* scenarios exist (*exploratory investigation*, see Table 1, subclauses 5.4 and 5.7, and clauses 7 and 8).

Typical application: to provide more information and better definition of the potential contamination identified in a) e.g. pre-purchase survey and due diligence audits.

c) *Objectives of investigation*: to provide sufficient information so that, where *contaminant-pathway-receptor* scenarios exist, the risks can be quantified (*main investigation*, see Table 1, subclauses 5.5 and 5.7, and clauses 7 and 8).

Typical application: to enable the identification and assessment of risks to those working on a site, to subsequent users, property or the environment, so that risks to these *receptors* can be managed, e.g. where a site is to be redeveloped.

d) *Objectives of investigation*: to provide information for the assessment of potential for future liabilities, for example due to contamination migration or a need for remediation when the land is redeveloped (can be *exploratory* or *main investigation*).

Typical application: used for the pre-purchase investigation of a business acquisition, which will continue to operate, i.e. part of a due diligence audit.

e) *Objectives of investigation*: to enable an assessment to be made of whether any significant pollutant linkages exist at the site which might lead to a requirement for remediation and the potential associated costs (can be *exploratory* or *main investigation*).

Typical application: part of the pre-purchase acquisition review or portfolio management action, considering the site in the context of Part 11A of the Environmental Protection Act 1990 [6].

f) *Objectives of investigation*: to provide information for the assessment of contamination and the determination of the cost of remediation for a proposed use (*main investigation*).

Typical application: where land is already owned and it is necessary to determine the contamination status, and hence the remediation that is necessary to bring it into beneficial use or for a specific redevelopment.

g) *Objectives of investigation*: to establish the current contamination status of a site.

Typical application: benchmarking for the purposes of IPPC, validation after remediation, benchmarking for insurance, financial or legal reasons.

5 Establishing an investigation strategy

5.1 General

Having determined the objectives of the investigation, a strategy needs to be developed to obtain appropriate, suitably robust and defensible data.

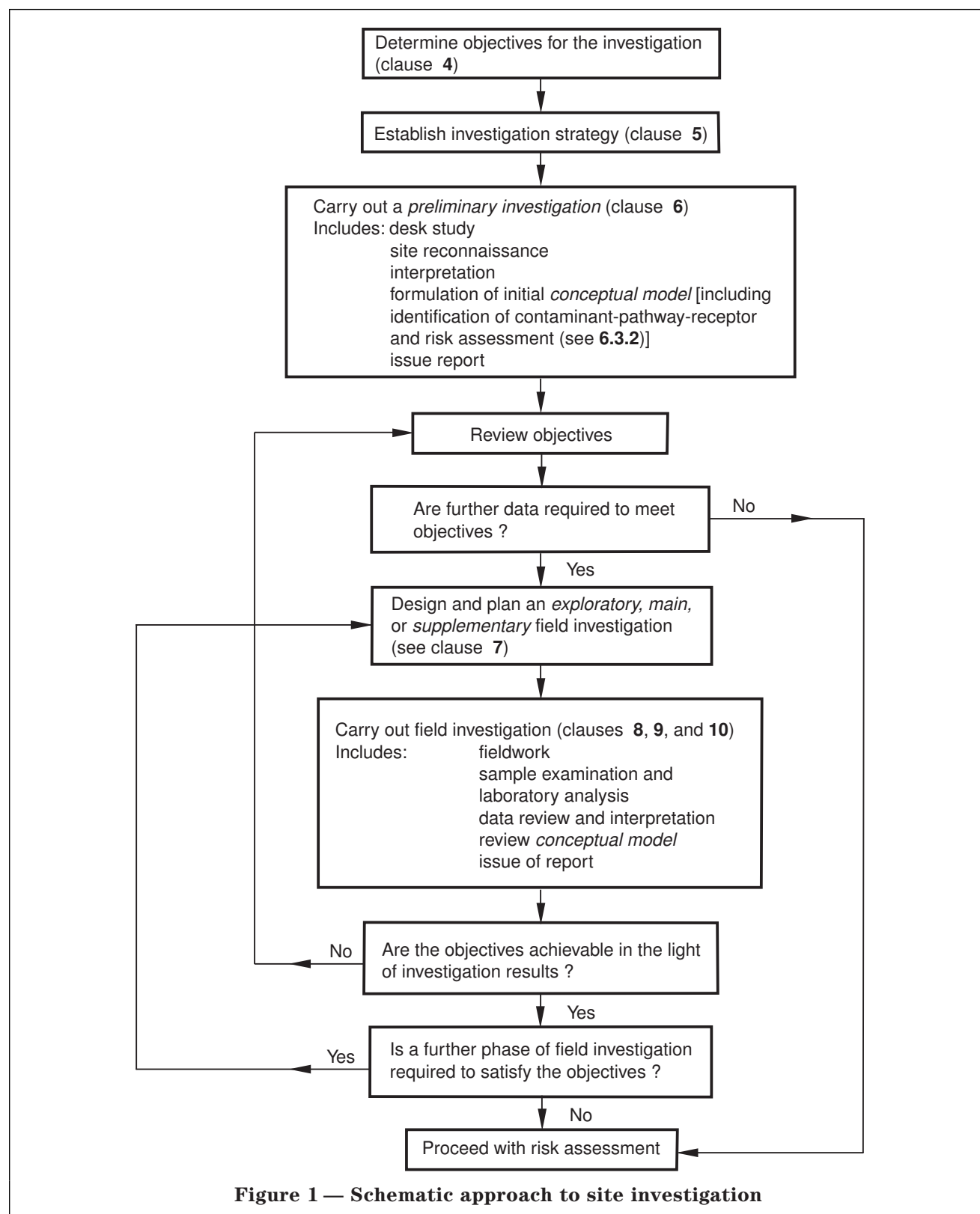
The different objectives of site investigations will, in particular, influence the selection of sampling locations, the number of samples analysed and to a lesser extent the analytical requirements.

5.2 Outline of strategy

The identification and delineation of contamination, the identification of areas of naturally enhanced concentrations of harmful substances and, particularly, the assessment of human and environmental risk can be complex. Because of this complexity, a site investigation should be carried out in a series of consecutive steps, each step designed to achieve specific objectives. The process of identifying and quantifying risks is an ongoing and iterative process. Several stages may be necessary to obtain sufficient relevant data to characterize potential *contaminant-pathway-receptor* scenarios.

The strategy should incorporate review stages so that data obtained is considered and decisions taken on the implications as the investigation proceeds.

Figure 1 shows a typical approach to site investigations, including the various stages of investigation. This illustrates how data and information obtained at each stage is reviewed in order to determine if the strategy requires modification, or the objectives have been met. This review process also enables the revision of the *conceptual model*, the requirements of the risk assessment and the objectives of the site investigation.



A strategic approach to the design of the site investigation will require careful consideration of the following:

- the objectives of the work;
- the site constraints;
- the available investigation techniques,

in order to select a process of investigation that will conform to all the requirements of the objectives as closely as possible.

For a pre-purchase assessment of land (to determine the degree of contamination and the potential remediation requirements), there can be a balance to be struck between the costs of the investigation and the amount of data to be collected since, if the project does not proceed, the cost of the investigation cannot be recouped by the client.

5.3 Preliminary investigation

The first step in the investigation process will always be a *preliminary investigation* (desk study) (see clause 6). The methodology for carrying out a fully comprehensive preliminary investigation is based on reference to historical records (6.2.1.2.1) and other sources of information (6.2.1.2.2), consultation with relevant sources (6.2.1.5) and a site reconnaissance (6.2.2). However, the objectives may not require such detail, in which case the strategy will identify what aspects of the *preliminary investigation* are necessary and those which do not need to be addressed.

For example, it may not be considered necessary to carry out a site reconnaissance (6.2.2) if it is known that the site is totally covered by recent building.

Where aspects of a *preliminary investigation* are not to be included, these should be agreed with the client and any limitations on the final assessment as a result of the omissions should be clearly understood by all the parties involved.

Even where information relevant to the *preliminary investigation* is already available, this should still be formalized into a *preliminary investigation* report.

The strategy should provide for a review of the information obtained on conclusion of the *preliminary investigation* to determine if the objectives have been achieved and if there is a need for proceeding with further investigation (6.3.3).

The output from the *preliminary investigation* should include the initial *conceptual model* (6.3.1) and a preliminary risk assessment (6.3.2) based on the information available. This may indicate that different areas of the site have different characteristics; for example some areas may be made ground and other areas natural ground: some areas may be potentially subject to contamination due to volatile organic compounds and other areas may be subject to potential inorganic contamination or there may be no indication of any contaminative use.

Where logical and appropriate the site may be divided into different zones or areas with different contamination potential, *contaminant-pathway-receptor* scenarios and *conceptual models*. Thus it will be realistic to have different requirements for the further investigation of different areas of the site.

5.4 Exploratory investigation

This may involve the collection and analysis of soil (7.6.2 and 8.3.2), surface water (7.6.3.8), groundwater (7.6.3 and 8.3.3), and soil gas (7.6.4 and 8.3.4) samples in order to obtain the information appropriate to the objectives.

An *exploratory investigation* may be used to obtain an indication that the initial *conceptual model* is generally correct before carrying out a *main investigation* to provide detailed confirmation.

Where the *conceptual model* output from the *preliminary investigation* identifies the likelihood of localized sources of contamination, e.g. fuel storage tanks, and there is inadequate information to do more than “guesstimate” the direction of groundwater flow, an appropriate strategy would be to carry out an intrusive *exploratory investigation* to provide information on the actual presence of contamination at the suspect locations and also to provide information on the water table in terms of groundwater flow and groundwater quality. Thus an *exploratory investigation* will tend to use targeted sampling locations (see 7.6.2.2).

It may be appropriate to consider the use of a non-intrusive investigation technique (see 7.5, 8.2 and Table 5) as an aid for locating below ground structures or other features of the site prior to intrusive examination as part of the *main investigation*.

It may become apparent as a result of the *exploratory investigation* that, for example, the contamination pattern is more complex or concentrations and/or extent are greater than anticipated. In such situations the information obtained is likely to be inadequate to make decisions with the necessary degree of confidence. It will be necessary to review the initial *conceptual model* and the requirements of the risk assessment. It is likely that it will be necessary to review the *preliminary investigation* information, and to carry out further investigatory work in order to refine the *conceptual model* and to provide adequate robust information for the risk assessment.

The review of the information obtained from the *exploratory investigation* may be such that a decision may be made that there is no need for further investigation. Alternatively, the information obtained may be used to design specific aspects of the *main investigation*.

5.5 Main investigation

This will involve the collection and analysis of samples of soil (7.6.2 and 8.3.2), surface water (7.6.3), groundwater (7.6.3 and 8.3.3), and soil gas (7.6.4 and 8.3.4) in order to obtain all the information necessary for the assessment of human and environmental risks. The detail required will depend upon the objectives of the investigation.

The further information and data should enable a full assessment of the risks presented by the contamination and also enable any containment or remediation actions to be properly designed with more accurate quantification of the costs.

This will require a carefully designed investigation, which should take into account the information developed in the earlier stages of investigation, and the objectives at this stage of the work.

During the subsequent assessment of risks and hazards, all possible migration routes relevant to the contamination should be considered and a four-dimensional picture (in space and time) of the contamination established. These requirements should be borne in mind when carrying out the design of the *main investigation* since to reach defensible conclusions, detailed knowledge of physical and chemical soil properties and of the local hydrology is essential (see Table 1).

The amount and nature of the information required from the *main investigation* will vary depending on the nature of the site, and the possible requirements for remedial action (see 5.3 on the need for differing investigations on different areas or zones of a site). The implications of the decisions on what actions should be implemented on a site will vary from site to site, and the amount and quality of the information will vary according to the confidence required in the decision making process. All parties involved in the decision making process should be kept fully informed as information is produced to check that the information is sufficient for the purpose intended.

The *main investigation* may involve some further targeted sampling points (for example at areas of specific concern in relation to potential contamination, or to achieve delineation of contamination confirmed/detected in the *exploratory investigation*). The greater proportion of the sampling points in a *main investigation* are normally non-targeted (see 7.6.2.3).

5.6 Supplementary investigation

A review of the outcome of the *main investigation* may still identify aspects where there is a deficiency of information. For example, to improve the accuracy of costing for a remediation may require further sampling to delineate an area of contamination or a contamination plume or more monitoring wells may be necessary to confirm the direction of groundwater flow. Where such deficiencies are identified, a supplementary investigation will be necessary. This will be designed to produce quite specific information and will therefore utilize targeted sampling (7.6.2.2).

When considering the costs of remediation it is likely that the collection of more detailed data will be necessary. Each remediation method (excavation, cover systems, in-ground barriers, biological treatment, thermal treatment, etc.) is likely to have its own data requirements and a supplementary investigation will be necessary to produce this additional data. Where contaminated soil or other materials are to be processed this may require characterization of the bulk of material including assessment of variability. It may be necessary to investigate the material or site more closely than for risk assessment and this may also have economic advantages, for example where discrimination between material requiring different treatment levels, types of treatment or disposal off- or on-site is made easier.

The on-going monitoring of groundwater and ground gas wells is also sometimes classed as supplementary investigation. The situation may arise where the results of monitoring as part of the *main investigation* indicate that longer term monitoring will be beneficial in enabling a better assessment of risks to be achieved.

Validation sampling carried out to confirm the efficacy of remediation may incorporate some targeted sampling (7.6.2.2) located at areas of specific remediation but will generally be non-targeted.

5.7 Investigation strategy

5.7.1 Where the risk assessment process requires more information than is obtained from the *preliminary investigation*, the strategy establishes how the necessary further information of an appropriate quality and amount will be obtained. This may involve non-intrusive and/or intrusive (collection and analysis of samples of ground, surface, and groundwater and ground gases) investigations (see 7.5, 7.6 and clause 8). The strategy of the further investigation will be formulated on the basis of the *conceptual model* and the information and gaps in the information from the *preliminary investigation*. The strategy will obviously also reflect the requirements of the risk assessment and the objectives of the investigation.

Sufficient time should be allowed between each phase of investigation to enable the information from one phase to be fed into the design of the next.

Consideration (including obtaining client approval) should be given to involving the regulatory authorities. This is particularly important for issues concerning controlled waters. Early involvement can help to prevent the inadvertent contamination of underlying groundwater resources, and can enable optimization of intrusive investigations and remediation strategy in line with any regulatory requirements.

The further investigation could take the form of an *exploratory investigation* to provide information, which will be useful in making the strategy for the *main investigation* cost effective. In some cases an *exploratory investigation* may not be considered necessary and the *main investigation* will be implemented.

Whichever further investigation is carried out after the *preliminary investigation*, including sampling for validation purposes, similar decisions will apply.

5.7.2 A suggested sequence of decisions is as follows.

- Decision 1 involves the consideration of the *conceptual model* in conjunction with the objectives. A conclusion needs to be reached on whether or not there is enough information to satisfactorily carry out the risk assessment with the required degree of confidence. If not, the objectives of the further investigation should be defined (see clause 4). In this consideration, a site does not necessarily need to be regarded as a single entity (see 5.3).
- Once the objectives of the further investigation have been established, the decision has to be taken on the form [non-intrusive and/or intrusive (see 7.5, 8.2 and Tables 5 and 6)] of the investigation that is necessary to obtain suitable data in accordance with the objectives.
- The next decision concerns the locations from which it is desired to collect samples and the number of locations required (see sampling strategy 7.6).
- Decision 4 involves the determination of the depths at which the samples should be collected (see 7.6.2.5) and the samples to be collected (i.e. soil, water, gas) and any monitoring requirements.
- Decision 5 concerns the determination of the purpose of the samples and the specification of what analyses should be carried out on them (see 7.7, 8.4, 9.4 and 9.6). (Consideration of the preservation of samples and other aspects of the reliability of the sampling is covered in 5.7.8).
- Decision 6 concerns the determination of which intrusive techniques are appropriate for collecting the samples (see Figure 2, Tables 7 to 9, 8.3.2, 8.3.3 and 8.3.4). This involves the consideration of the soil types, groundwater conditions, topography, services and access, (e.g. soft landscape, tarmac, presence of buildings), what quality of reinstatement is necessary, at what depths samples are to be collected (7.6.2.5), whether a soil gas investigation is included (7.6.4), whether water samples are to be collected (7.6.3) and what monitoring installations are required (7.6.3 and 7.6.4).

The selection of the sampling technique may involve some compromise; for example, if samples are only required to 2 m to 3 m below ground level, trial pits might be regarded as the best technique. However, where there is oversite concrete which is still in use and a good standard of reinstatement is necessary, in order to minimize disruption of the site and allow satisfactory reinstatement, coring through the concrete followed by use of a window sample could be the preferred strategy (see Figure 2 and Tables 7, 8 and 9).

- Decision 7 has regard to a variety of aspects connected with the quality of samples (see 7.8, 8.3.1, 8.5, 8.6, 8.7 and clause 9):
 - how samples are to be taken to avoid or minimize cross-contamination (8.3.1.1);
 - how samples are to be preserved to avoid alteration prior to analysis (8.6);
 - requirement for on-site instrumentation (8.4);
 - what provisions need to be taken for cleaning of on-site equipment between sampling points (8.3.1.1);
 - establishment of the necessary quality assurance procedures to provide an auditable process to enable confirmation that sampling has been carried out in a satisfactory manner (7.8);
 - selection of a suitable laboratory which can accommodate the workload (see clause 9).

- Subsequent decisions include the selection of the on-site project manager (7.3) and the programme for the field works.

Further actions include the detailed briefing of the on-site project manager and the incorporation of their input, the establishment of the logistics of the site investigation, including the availability of relevant machinery and personnel, permission for site access, liaison with regulatory authorities, and COSHH and risk assessments (annex B).

5.7.3 Following the completion of the site works the on-site project manager should ensure that the site has been left in a safe and satisfactory condition in accordance with the investigation specification. The despatch of samples to the laboratory and the confirmation of instructions to the laboratory, including the expected date for reporting, should be established so that the reporting process can be controlled.

5.7.4 Those who are to make the decisions required to develop a satisfactory strategy, should have experience of site investigation work. This experience is necessary in order to determine what information is required from the site investigation in order to achieve the objectives (Table 1 gives typical examples of the data and information, which may be sought at different stages of the investigation).

These decisions also require knowledge and experience of the different investigatory techniques which are available and which may be relevant. Clauses 7 to 9 set out the main issues that require consideration when selecting suitable techniques, with guidance on what data and information may be relevant and how the techniques may be used in obtaining that data and information.

6 Preliminary investigation

6.1 General

A *preliminary investigation* should always be carried out before any systematic sampling or analysis is specified or undertaken (see 5.3).

NOTE In publications [11], [14], [15] a *preliminary investigation* is referred to as a “Phase 1” investigation.

The principal aims of the *preliminary investigation* should be to obtain information in order to:

- assess the likelihood of finding contamination, its nature and its extent;
- evaluate the environmental setting of the site and to identify sensitive *receptors*;
- provide information from which likely *contaminant-pathway-receptor* relationships can be identified. This can then be used to formulate a *conceptual model* to enable the design of an effective field investigation (if required);
- determine the requirements for further investigation, (if any);
- identify any special procedures and precautions that will be necessary during subsequent sampling and examination of the site.

A *preliminary investigation* is a two step process involving data collection followed by interpretation (see Table 2).

The specific scope of each stage of the *preliminary investigation* will vary according to the overall purpose of the investigation, the availability of existing information, the size and complexity of the site, known or projected future land uses and other relevant site-specific factors.

Table 2 — Preliminary investigation

Step	Activity
Data collection	Desk study <i>Documentary research:</i> — site history (location, surroundings, topography); — site usage (including adjacent areas); — site geology, hydrogeology, geochemistry, hydrology; — site ecology and archaeology. <i>Consultations</i> (see Table 3)
	Site reconnaissance: — detailed inspection; — interviews; — limited ad hoc sampling and field measurements (if appropriate).
Interpretation and reporting	Formulate initial <i>conceptual model</i> . Undertake preliminary risk assessment. Assess need for, and scope of, further investigation. Prepare report.

6.2 Data collection

6.2.1 Desk study

6.2.1.1 General

The desk study should comprise a combination of documentary research (see 6.2.1.2) and consultations (see 6.2.1.3).

The desk study should cover the following topics, where appropriate:

- a) the history of the site and adjoining areas. Particular attention should be paid to the nature of any industrial processes or other activities on the site that could have been potentially contaminative or could have modified the ground structure to create potential migration *pathways*;
- b) any previous desk study or investigation of the site;
- c) the geological, geochemical, hydrogeological, hydrological, archaeological and ecological setting of the site;
- d) potential *receptors* of contamination (for example, current and intended users, trespassers, surface waters, groundwaters or nearby water abstractions, property);
- e) the proximity of any licensed or unlicensed waste disposal sites or other sources of contamination, including hazardous gases, that could have an impact on the site;
- f) the existence of naturally occurring harmful materials such as radon or naturally enhanced concentrations of harmful substances;
- g) the presence of any mining activities;
- h) any constraints on an intrusive site investigation (access or height limitations, underground services or obstructions, noise, working hours, etc.).

6.2.1.2 Documentary research

6.2.1.2.1 Site location and historical setting

The level of historical research undertaken should be compatible with the objectives of the investigation.

The site location and site boundaries should be accurately established with the purchaser of the study (client) before commencing any investigatory work.

The site history should be determined using either the following or any other appropriate sources of information:

- Ordnance Survey maps;
- other published maps, for example, insurance, tithe, enclosure or parish maps;
- aerial photographs;
- documentary records held by the current (and former) owners of the land, trade directories, the local authority and local libraries.

Table 3 gives a list of the types of information held by national and regulatory bodies.

For further details of the information held by different parties, see CLR 3 [16] published by the DETR.

NOTE Over-reliance should not be made on past OS map editions since they may not represent a complete record of historical land use.

Table 3 — Types of available information

Agency	Information
Environment Agency (EA), Scottish Environment Protection Agency (SEPA), Environment and Heritage Service (EHS) Northern Ireland.	Information held on groundwater and surface water quality; information on pollution incidents; IPC and IPPC authorizations, current groundwater abstraction licences; operational and closed landfill and waste treatment sites, Special Sites.
Local authorities	Information held on contaminated land remediation. Historical experience of environmental nuisances. Conditions of any planning consents. Closed landfill sites and private water abstractions.
HSE and Fire Authorities	Records of accidents and incidents.
Petroleum Officer	Location and status of fuel storage tanks.
Coal Authority	Mining records.
National Radiological Protection Board (NPRB)	Maps and information on radon in England and Wales.

6.2.1.2.2 Site usage and contamination

Details of the past and current usage of the site, and its immediate environs including background concentrations, together with information on any incidents (such as spills or detected leakages) should be collated and used in the development of the initial *conceptual model*.

Land can become contaminated from a wide range of activities on the site, or on adjacent areas. Industrial sites (where contamination is likely) include, but are not limited to:

- landfill sites, other waste treatment, recycling and disposal operations and land surrounding these sites;
- sites of heavy industry;
- power stations or electricity substations and coal carbonization sites including gas works;
- chemical and manufacturing plants, particularly those involving hazardous processes, for example, using or storing bulk liquid chemicals or discharging significant quantities of effluent;
- sewage farms and sewage treatment plants;
- breakers' yards;
- railway sidings;
- all works employing metal finishing processes (for example plating, paint spraying);
- fuel storage facilities, garages and petrol forecourts;
- former mining sites (particularly mines for metal ores);
- engineering works;
- works utilizing animal products, for example, tanneries;
- Ministry of Defence sites;
- timber treatment works.

The following information sources contain details of existing research into contamination issues associated with different industrial uses of land and should be consulted, where appropriate.

- CLR 3 published by the DETR [16];
- Industry Profiles, published by the DETR [17] (see Further reading on page 73 for a listing of the industries covered);
- Guidance Notes published by the Interdepartmental Committee on the Redevelopment of Contaminated Land [18];
- Appendix A of the Advice Note in Design Manual for Roads and Bridges [19].

NOTE Handbook of model procedures [12], which is in the process of development by the DETR and Environment Agency, will also be a source document when published.

The documentary research should ascertain, if possible, whether any of the following occurrences (common causes of contamination) have taken place:

- a) spills or leaks of noxious liquids from tanks, pipes and drains on the surface, or underground;
- b) deposition or burial of industrial or domestic waste, or temporary stockpiling of leachable materials (for example, road salt);
- c) demolition of industrial structures and dispersal or burial of contaminated rubble and other materials;
- d) importation on to the land of contaminated fill material.

Table 3 gives details of the information held by national and local regulatory authorities. See also 6.2.1.3 for other information that should be discussed with regulatory authorities.

6.2.1.2.3 Geology, geochemistry, hydrology and hydrogeology

All readily available sources of information on the geological, geochemical, hydrological and hydrogeological conditions of the site should be collected and examined.

The following sources can be consulted:

- British Geological Survey (BGS) for geological, geochemical and hydrogeological maps¹⁾;
- Environment Agency for groundwater vulnerability maps^{2) 3)} and information on source protection zones; and
- the results of any previous ground investigations carried out on the site or information from national surveys covering the vicinity.

NOTE BS 5930 gives a comprehensive list of geological information sources. The supplement published in the Quarterly Journal of Engineering Geology [20] also contains useful information¹⁾.

¹⁾ More information can be obtained from British Geological Survey, Keyworth, Nottingham NG12 5GG. Tel 0115 936 3143.

²⁾ More information can be obtained from the local Environment Agency office.

³⁾ In Scotland, groundwater vulnerability maps can be obtained from BGS – see footnote 1) above.

6.2.1.2.4 Ecology and archaeology

If a site (or its immediate environs) has been designated as an area of ecological or archaeological significance, it is likely that there will be constraints on the methods of ground investigation that can be used.

The following sources should be contacted to check if a site has a particular designation.

- English Nature/Scottish Natural Heritage/Countryside Council for Wales, for Sites of Special Scientific Interest⁴;
- Ministry of Agriculture, Fisheries and Food (MAFF) for Environmentally Sensitive Areas⁵;
- The local authority for any information included in their Development Plan. (These plans identify sites of national and international importance as designated by English Heritage, Countryside Council of Wales and Scottish Natural Heritage, respectively, as well as sites of county and local importance.)

There may be species or habitats of importance or subject to legal protection under the Wildlife and Countryside Act or Habitat Regulations that are not in designated sites (for example nesting birds, water voles).

6.2.1.3 Consultations

Consultation should be carried out with relevant parties, normally in parallel with the documentary research. Interviews with persons holding knowledge of activities on, or adjacent to the site, may be combined with the site reconnaissance visit. Such interviews provide the best opportunity to indicate suspect locations or features, underground services, etc. but anecdotal evidence should be viewed with caution.

Consultations with the regulators should include discussion of acceptable methods of ground investigation. It is vital that potential risks to groundwater, caused by the accidental creation of migration routes during boring or trial pitting, are minimized. Client approval should be obtained before starting such consultations. If investigations are likely to be undertaken on (or accessed via) ecologically sensitive sites or agricultural land, English Nature, Countryside Council of Wales, Scottish Natural Heritage or local MAFF office should be consulted to discuss acceptable methods of work.

6.2.2 Site reconnaissance

A reconnaissance of the site, neighbouring land and the local area should be made, where necessary and agreed with the client, ideally after carrying out documentary research (see also 6.2.1). Permission for access to the site should be obtained from the owner and/or occupier as appropriate.

The purpose of the visit should be to:

- a) validate information on the site collected during the desk study;
- b) collect additional information about the site, its environs, and any potential *contaminants, pathways* and *receptors*;
- c) record observations of aspects of the site not revealed by the desk study;
- d) assist in the planning of any subsequent phases of field investigation (taking into account any constraints to access).

A strategy for the visit should be decided in advance and suitable plans, checklists and reference documentation prepared.

A COSHH assessment should also be carried out. This is particularly important on former industrial sites and waste sites. In the case of the site reconnaissance, the hazard assessment should be based on the results of the desk study. It may be possible to refine the assessment once the preliminary investigation is completed. It should be kept under review as the investigation proceeds but where there is any doubt as to the presence or degree of contamination then protective equipment should be used. Personnel undertaking the visit should be thoroughly briefed on any hazards that could be encountered and on any precautions to be taken.

If operational buildings still exist, a review of the past and present usage of the property could be relevant and should be carried out, if required.

If possible, personnel should be accompanied by someone familiar with the site (such as a plant manager or safety officer in the case of an industrial site). During the site visit photographs of salient features should be taken, where permissible.

⁴ More information can be obtained from English Nature, Northminster House, Peterborough PE1 1UA. Tel 01733 455 000 or email enquiries@english-nature.org.uk; Scottish Natural Heritage, 12 Hope Terrace, Edinburgh EH9 2AS. Tel +44 (0)131 447 4784 or email enquiries@snh.gov.uk.; The Countryside Council for Wales, Plas Penrhos, Penrhos Road, Bangor, LL57 2LQ. Tel. 01248 385500 Web site: www.ccw.gov.uk.

⁵ More information can be obtained from MAFF, North Regional Service Centre, Edenbridge House, Carlisle CA3 8DX.



A reconnaissance of the site may not always be necessary, for example where it is fully developed, and useful information will not be derived. In some situations the client may not require site visits. In such cases the agreed specification for the preliminary investigation should clearly state that a reconnaissance is not included in the work to be carried out.

Since a reconnaissance is part of the process of collecting information relating to the site, it is premature to carry out systematic sampling at this stage; for example, any problems of access will not be appreciated before the visit. However, testing for ground gases by driving a spike into the ground (spiking test) may also be carried out (see 7.6.4). Such testing should only be carried out if service plans are available and spiking locations are checked with a cable avoidance tool. See 7.3 for further details.

Additional, detailed guidance on carrying out preliminary field inspections of potentially contaminated land is given in the following publications:

- CLR 2 published by DETR [21];
- SP103 published by CIRIA [11].

6.3 Interpretation and reporting

6.3.1 Formulation of initial conceptual model

Guidance on formulating an initial *conceptual model* is outside the scope of this standard.

ASTM E1689-95 [43] gives guidance on formulating a *conceptual model*.

The information from the documentary research, site reconnaissance visit and consultations should be collated and evaluated to formulate an initial *conceptual model* of the site.

The initial *conceptual model* should identify, as far as possible:

- potential types and depths of contamination present in different zones of the site;
- the likely vertical and horizontal stratification of natural and manmade layers beneath the site;
- strata variability (occurrence and thickness) in different areas of the site, and their relative permeability, both vertically and horizontally;
- potential migration routes (including airborne dispersion);
- the presence of services trenches, drainage runs, underground storage tanks, former foundations, and any other physical features that might influence the occurrence or migration of contamination. (Features which might provide a constraint to investigation, such as power lines, should also be identified);
- the occurrence of any biological, chemical or physical processes that might affect *contaminant* concentrations and migration (including natural attenuation);
- the characteristics of groundwater bodies beneath the site, groundwater levels and flow directions;
- the presence of surface water bodies on, or adjacent to the site;
- other potential receptors.

NOTE The initial *conceptual model* may also include hypotheses of the presence of made ground, underground obstructions, buried river channels, the expected directions of groundwater flow, number of aquifers and details of groundwater recharge, permeability of the ground, the physical and chemical properties of the expected *contaminants*, their possible degradation products, the location and form of the *contaminant* source, duration, etc.

When further investigations are carried out the additional information should be used to refine the *conceptual model*.

6.3.2 Preliminary risk assessment

Guidance on carrying out a formal risk assessment is outside the scope of this standard. However, the risk assessment is likely to include the following aspects:

- a) identification of *contaminants*, *pathways* and *receptors*;
- b) estimation of the likelihood, nature and extent of exposure to a hazard; and the risk of adverse effects;
- c) assessment of the likely pollutant linkages and the degree of risk;
- d) evaluation of the need for controlling the estimated risk.

Where the existence of adequate site investigation information has been revealed by the *preliminary investigation*, a quantitative, or semi-quantitative, risk assessment can be undertaken. Information from previous investigative works should be either verified or used with caution. However, where little or no previous investigation has been undertaken, only a qualitative assessment can be made. The effects of uncertainties in the information available on the outcome of a risk assessment should be identified.

NOTE The handbook of model procedures [12], which is in the process of development by the DETR and Environment Agency, will provide guidance on risk assessment when published.

6.3.3 Further investigations

The findings of the *preliminary investigation* should form the basis upon which the requirement for, scope of, and phasing of, subsequent investigations are decided.

The risk assessment and the objectives of the investigation should be reviewed and the need for further investigation considered.

This decision will depend upon the quantity and quality of previous site investigation information available, the level of confidence required from the actual characterization of ground conditions and hazards, and the results of the risk assessment.

6.3.4 Reporting

The *preliminary investigation* should be completed by the issue of a report. Subject to the specific brief for the investigation the report ideally should include the factual results of the desk study, site reconnaissance and consultations, together with the conclusions drawn, (including presentation of the *conceptual model*), and recommendations on any further research and/or ground investigation to be carried out. The report should also describe the results of the preliminary risk assessment.

NOTE For further guidance on reporting, see clause 10.

7 Design and planning of field investigations

7.1 General

The field investigation should be designed in accordance with the objectives (see clause 4 and Table 1) to provide further information to enable revision and updating of the *conceptual model* and the risk assessment. Strategy for field investigations is discussed in clause 5 where three types of field investigations are identified:

- *exploratory* (see 5.4 and 5.7);
- *main* (see 5.5 and 5.7);
- *supplementary* (see 5.6 and 5.7).

For each of these investigations the *conceptual model* is at a different stage of development and there can be a need for different information with different degrees of confidence. For example, in the *exploratory investigation* information confirming the presence of a potential *contaminant* may be required, whilst in the *main investigation* the same area needs to be much more accurately defined and migration *pathways* confirmed. In the *supplementary investigation* the delineation of migration *pathways* needs to be determined to a degree of accuracy to enable costing for remedial work to be calculated.

Typical field investigations should be designed to:

- determine (with a degree of confidence appropriate to the objectives) the presence, concentration and distribution of *contaminants* on the basis of the *conceptual model* and the information currently available;
- consider ground and groundwater conditions including hydraulic gradient, soil permeability, porosity, density, moisture, particle size, etc., as these can influence contamination movement;
- characterize any potential *pathways* in terms of migration and possible attenuation;
- where known contamination exists, collect additional data for the delineation and design of remediation plans.

The investigation should be designed to confirm the extent of contamination in areas where it is suspected, and to confirm the absence of contamination in the rest of the site. The analytical suite should include testing for both commonly occurring *contaminants* and for those linked to the historical activities on the site.

If it is necessary to demonstrate that a site is uncontaminated, a detailed investigation covering the entire site should be carried out. The intensity of the investigation will depend on the degree of confidence required in assessing whether there is an absence of contamination.

Migration of contamination off-site, or on to a subsequently remediated site, is an important consideration. In situations where there are potentially sensitive *receptors* or sources of contamination located outside the site, the fieldwork should include investigation at, or beyond, the site boundary. In practice, however, off-site access can be restricted due to land ownership. Permission for access to such adjacent areas should be obtained.

Where relevant, site investigation proposals should be discussed with the Environment Agency and the local authority for the area (in order to incorporate any specific measures and gain confidence that the outcome of the investigation will satisfy regulatory requirements) can be necessary (see 6.2.1.5).

The permission of the site owner should be obtained, preferably in writing, prior to the commencement of the site investigation.

7.2 Integrated investigations

Integrated investigations that meet the needs of both contamination and geotechnical aspects can offer benefits. Integrated investigations have the following advantages:

- simplified project management;
- common use of equipment and procedures;
- exploratory holes can be used for more than one purpose;
- joint health and safety procedures can be established;
- joint environmental protection procedures can be established;
- integrated consideration of resultant data.

Linking the work with other types of studies can also be appropriate in some circumstances. In particular, the ecological survey of a site and surrounding area may indicate contamination on the basis of observed impacts on flora. Archaeological and contamination investigations can share information from geophysical survey work (see 8.2.2).

The degree of integration should be based upon the findings of the *preliminary investigation*. Any integrated investigation, using multi-disciplinary teams, however, should be designed so that it does not compromise the requirements of either investigation. For example, sampling locations for contamination should not be moved from a selected grid pattern (see 7.6.2) in order to accommodate geotechnical requirements.

7.3 Personnel and environmental protection

Guidance on site safety issues that should be addressed in any investigation is provided in annex B, to which reference should be made.

It is important that personnel, in particular the team leader(s), have an adequate understanding of the technical issues involved. See also 7.8. This requires knowledge and experience of investigation and sampling techniques, and an appreciation of the characteristics of the materials likely to be encountered. Personnel should have a working knowledge of the health, safety and environmental issues involved. The following publications give additional guidance.

- CLR12 published by DETR [22];
- Good practice in site investigations, published by the Association of Geotechnical and Geoenvironmental Specialists [23];
- HS(G)66 published by HSE [24];
- Guide R132 published by CIRIA [25];
- ISO/DIS 10381-3;
- Guidelines for the safe investigation by drilling of landfills and contaminated land, published by the Site Investigation Steering Group [45].

It is essential that investigations avoid creating a nuisance to neighbouring residents or occupants, or creating a hazard to the environment.

Any services should be located and identified by reference to the utility companies or to service plans for private land and by using services detection equipment, to prevent accidental damage. The area of sampling locations should also be visually inspected for possible services prior to commencement of an intrusive investigation.

7.4 Pre-investigation considerations

7.4.1 Demolition and clearance

Where buildings exist, but are to be removed as part of a redevelopment, it is sometimes necessary to carry out the field investigation in two stages. Accessible sample locations can be investigated initially and the remainder can be accessed after demolition has occurred. If buildings are dilapidated, great care should be taken to prevent the site investigators being exposed to risks posed by the buildings, for example, asbestos fibres or falling masonry.

When demolition is carried out, attention is drawn to statutory requirements for CDM designer risk assessments and Health and Safety plans [9]. Prior to demolition a specialist survey should be undertaken to determine the nature and extent of the hazards present. This can sometimes necessitate sampling and testing to establish the contents of vessels and pipework, the presence of contaminated building fabric or the presence of asbestos.

All demolition should be undertaken in accordance with BS 6187.

Some buildings require special procedures to be followed before the site is cleared, for example, if hazards from asbestos, radioactive substances or biological organisms are present. Where the site history shows that such hazards are likely to be present, the engagement of specialist decontamination or demolition contractors is essential.

Care should be taken to avoid spreading contamination during site clearance work as indiscriminate demolition can lead to greatly increased decontamination costs.

Further guidance can be obtained from SP 102 published by CIRIA [46].

7.4.2 Disposal of rubble and waste materials

Tanks and pipes (both above and below ground) and cavities can contain significant amounts of hazardous substances long after an industrial site has closed. Damage to tanks, pipes and drains or the relocation of materials within the site can result in the spread of contamination.

If any residues or raw materials are present, especially in liquid form, consideration should be given to the nature of the material and the need for removal before site clearance or sampling begins. This can necessitate a separate preliminary sampling exercise prior to removal.

Intrusive investigations themselves can often lead to the generation of waste material including spoil and groundwater. Suitable disposal routes should be identified and arranged before the work begins. However, analytical data are likely to be necessary before a suitable disposal route can be confirmed. In the intervening period the material should be made secure.

NOTE 1 The investigatory team is responsible for the safe disposal of “arising” both solid and liquid to a suitably licensed location under the Environmental Protection (Duty of Care) Regulations 1991 [26].

NOTE 2 Certain materials are designated “Special Waste” and the appropriate environment agency requires notification prior to disposal. Attention is drawn to the Special Waste (Amendment) Regulations 1996, [27].

7.5 Method of field investigation

7.5.1 General

The strategy of the field investigation (see clause 5) should be formulated to suit the objectives and site specific features. Investigation of a site can be carried out by non-intrusive and/or intrusive methods.

7.5.2 Non-intrusive

Non-intrusive investigations can be carried out using a range of technologies; the advantages and disadvantages of which are discussed in 8.2.2 and Table 5.

These methods can be useful within a *preliminary investigation* or as part of an *exploratory investigation* where the presence, but not the specific locations, of features associated with contamination is suspected.

The feasibility of using non-intrusive techniques can be dependent on ground conditions and the features of interest, and should be selected for a particular site by discussion with specialists in relevant methodologies.

7.5.3 Intrusive

The objectives of most field investigations will result in a need to collect samples of soil, water, and soil gas and there are different technologies available for such sampling. The technologies selected will be chosen having regard to the samples to be collected, the locations and depths of sampling and the constraints of the site (e.g. limited access, hard landscape).

The methods of carrying out intrusive investigations, including the installation of permanent and semi-permanent monitoring wells, are discussed in 8.2.3 and Tables 6 and 7, where the advantages and disadvantages are described.

Where groundwater or soil gas contamination is suspected, monitoring wells that allow specific sampling requirements to be met should be installed. Water samples obtained during trial pitting and drilling may be screened for the presence of groundwater contamination and to establish the need to install monitoring wells. However, caution should be applied when considering the analytical data from such samples, since the ground disturbance caused by the drilling or digging can affect the composition of the water sample.

It is essential that the need to prevent contamination migration (caused by the creation of temporary or permanent connection between aquifers or between contaminated ground and underlying aquifers) is considered when selecting an investigation technique (see 8.2.3.1).

In many cases it is advisable to discuss investigation proposals with the appropriate environment agency in order to incorporate their particular requirements.

In order to select appropriate sampling techniques for investigation, the requirements for sampling need to be established and the remainder of clause 7 provides guidance on determining where, what type and at what depth samples should be collected and monitoring facilities installed. Sub-clause 8.3 provides details, plus indications of the advantages and disadvantages, of the various sampling techniques that are available for carrying out an intrusive investigation.

7.6 Sampling strategies

7.6.1 General

The sampling strategy for any phase of intrusive investigatory fieldwork that follows the *preliminary investigation* should identify the following:

- a) the objectives of the investigation and the possibility of zoning the site (see 5.3);
- b) the location, pattern and number of sampling points (see 7.6.2.1 to 7.6.2.4);
- c) the depths from which samples should be collected, the samples to be collected and any monitoring requirements (see 7.6.2.5);
- d) the analyses required and whether any in-situ or on-site testing is appropriate and necessary (see 8.4.2 and 9.1);
- e) the methodology by which samples should be collected (clause 8), stored and preserved (8.6), taking into account any off-site analysis to be undertaken (see clause 9);
- f) any safety measures needed to protect personnel or the environment (see 7.3 and annex B).

Additional site-specific factors, (for example, the site size and topography, depth of groundwater and its direction of flow or any physical obstructions) should be identified.

The sampling strategy should allow flexibility so that representative samples of all strata and materials encountered, are collected, including any anomalous material.

The investigation design should address the needs of the risk assessment. For example, the number of samples for site characterization or statistical analysis should be sufficient for the chosen methodology. The reason(s) for choosing a sampling strategy (including the choice of locations and frequency of sampling) should be included in the final report (see 10.3).

Potential heterogeneity of distribution of *contaminants* should be taken into account when designing the sampling strategy, particularly in relation to the risk assessment and the degree of confidence required, since this will have an impact on the sample locations selected and the number of samples collected (see 7.6.2).

It is important that any sample submitted to the laboratory is representative of the location and depth from which the sample was taken (see annex D for the collection of a representative soil sample). Greater confidence in the site assessment can be achieved by increasing the number of samples taken and analysed, as significant differences in the sample composition over small areas within the site can occur. The errors associated with sampling in site investigations are generally greater than those associated with the analysis. It can therefore be more informative to analyse a greater number of samples using methodology fit for the purpose, than to analyse a smaller number of samples using a more accurate method.

Water bodies tend to be more homogeneous in composition than soil. A water sample can represent a far greater volume of water than can a corresponding sample volume of soil. However, stratification can still occur in groundwater and surface waters. This should be taken into account in the design of the sampling strategy. Allowance should also be made for contamination migrating against the direction of water flow, for example, where the direction of movement of dense non-aqueous phase liquids permeating into the ground is affected by impermeable material such as obstructions or clay (see also 7.6.3.5).

Soil gas samples are similar to water samples in that they can be representative of a large zone. Nevertheless, the sampling strategy differs from that used for waters because of the greater ability of soil gases to migrate in all directions within the ground. Where monitoring locations for groundwater and soil gases are coincident, it is not always possible to install a joint monitoring well.

The sampling strategy should take into consideration the possibility of creating routes for migration (see 7.6.3.6).

Where near surface samples are not required and samples are required only at greater depth within the ground, an appropriate method of rapid development of the borehole to the required depth may be used. Care should be taken, however, to protect the bore and to clean out material before taking a sample, to avoid cross-contamination (see 8.2.3.3).

Equipment should be cleaned between use at different sampling locations and within locations when forming boreholes, to prevent cross-contamination of samples (see 8.2.3.3).

Sampling locations should be surveyed accurately, in both plan and elevation, from permanent marks which should preferably be related to Ordnance Survey Grid and Datum. The use of Global Positioning Systems (GPS) should not preclude the inclusion of permanent marks.